

GROWTH OF SOLAR PHYSICS RESEARCH OUTPUT IN INDIA SINCE 1960: A SCIENTOMETRIC ANALYSIS

*Md. Nurul Alam
Archana Shukla*

The purpose of this study is to assess the current state of published output on 'Solar Physics' in India. In this context, a scientometric study was conducted to evaluate Solar Physics research during the period 1960-2014 from different perspectives. During the period, a total of 2066 articles were published on Solar Physics, which received 22254 citations. The average number of publications per year was 48.04 and the average number of citations per publication was 10.77. The publications peaked in the year 2014 with 168 publications and the highest number of citations (1546) was in 2009. The present study shows that Solar Physics research has increased steadily over the past 54 years on a sluggish rate. Articles on Solar Physics appeared in 92 journals, of which most active journal was "Solar Physics" published by Elsevier from Netherlands with 460 (22.265 %) of the total 2066 articles. Of the 1109 institutions that have contributed, Indian Institute of Astrophysics, Bangalore (549) is the most productive institution. Of the 65 Countries/territories which have participated in Solar Physics research, USA produced maximum number of 420 publications, with higher citations (8711). A Keyword analysis reveals that Corona, Flares, Magnetic Fields, Coronal Mass Ejections, Activity, Oscillation, Atmosphere are the most used keywords.

Keywords: Solar Physics, Scientometrics, Bibliometrics, Growth, INDIA

INTRODUCTION

The study of the Sun, or solar physics is an important area of Astronomy and Astrophysics in India that grew out of an already well-established tradition of astronomical observations [1]. Solar physics plays a unique role in astronomy which is a major part of space science. It is the field in classical astronomy that claims significant societal relevance, extending from the obvious direct influence of the solar luminosity on planetary habitability, to the more subtle impacts of Space Weather on human civilization and commerce. Solar physics also is unique in contemporary stellar astronomy in having a next-door view of it's (albeit singular) subject, even to the extent of directly capturing particulate matter in the extreme outer limits of the solar atmosphere [2].

Solar Physics is an important area of Astronomy and Astrophysics in India that grew out of an already well-established tradition of astronomical observations. There has been increasing importance for doing research in Solar Physics. There has been no published Scientometric study of research on the Solar Physics. Therefore, the aim of this paper is to carry out a Scientometric evaluation of the research on the Solar Physics published and during the last six decades to identify the main trends and issues in this field.

Md. Nurul Alam
Library and Information
Services,
Physical Research
Laboratory, Navrangpura,
Ahmedabad – 380009,
alam@prl.res.in

Archana Shukla
Department of Library &
Information Science,
IGNOU, SOSS,
Maidan Garhi,
New Delhi-110068
archana@ignou.ac.in

METHODOLOGY

Database and Scope Filtering Process

To assess the growth of research publications in Solar Physics and locate and collect the literature, Web of Science (WoS) was searched using a number of appropriate keywords for literature within a time span of 1960-2014. The Search Strategy used to conduct Web of Science (WoS) search is: TS= "Solar Physics" OR "Sun" = (Search Term) Where TS is a topic search that retrieves occurrences of the search term in the article title, abstract, keywords. This process was followed for another series of search terms given by Astronomical Subject Keywords [2013]. These were used to locate publications that contained the words in publications' titles, abstracts, and keyword lists.

Filtering Process

An extensive search of the Web of Science (WoS) database retrieved a vast amount of data. Resulting articles were filtered by Subject category- Astronomy & Astrophysics followed by Document Types: (Article), and Languages: (English). The filtered articles were again filtered by Countries/Territories: (INDIA). This final round of filtering produced 2066 (Astronomy & Astrophysics) articles which were examined.

RESULTS AND ANALYSIS

The specific characteristics of the publications such as number of publications, the number authors involved in the production of these publications, institutions, journals, etc. were taken into consideration for analysis (table1).

Table 1: Publication Characteristics

Total Number of Articles	2066
Total Number of Contributing Countries	65
Total Number of Contributing Authors	4487
Total Number of Contributing Institutions	1109
Total Number of Journals Appeared	91
Total Number of Keywords (raw) Appeared	5666

A total of 2066 articles of Indian scientists during 1960-2014 were retrieved from WoS related to Solar Physics publications. These 2066 papers received a total of 22254 citations during the said period with an average of about 10.77 citations per paper. The average number of publications per year is 48.04 and CAGR is 0.09% (table 2).

Table 2: Citation Metrics of Solar Physics Research in India during 1960-2014

Citation-Based Indicators	Number
Times Cited	22254
Times Cited without Self-Citations	18385
Citing Articles	13658
Citing Articles without Self-Citations	12389
Average Citations per Item	10.77
h-index	59

Publication Pattern

Publication pattern of Solar Physics research from 1960 to 2014 is presented in Figure 1. A paper in the sub-field Solar Physics research was published in the year 1972. The number of papers increased approximately fifty times from 3 in 1972 to 168 in 2014. The highest number of papers is published in the year 2014, with 168 publications and the lowest in 1979 with 1 publication.

Growth Trend

The distribution during 1960-2014 giving an idea of the growth is shown in Figure 2. To choose the best fit growth model, various regression types with regression coefficient have been tested as shown in Table 3. The best fit model is 4th degree polynomial curve, where $R^2 = 0.941$. The polynomial best fit for Solar Physics research is found to be: $y = 0.0003x^4 - 2.1734x^3 + 6490.4x^2 - 9E+06x + 4E+09$, where y is the cumulative number of publications and x is the number of years. The growth of literature shown in Figure 2 can be divided into two parts, in the 1st part (1960-1971), no literature is published by Indian scientists and in 2nd part (1972-2014), the trend follows a polynomial growth curve.

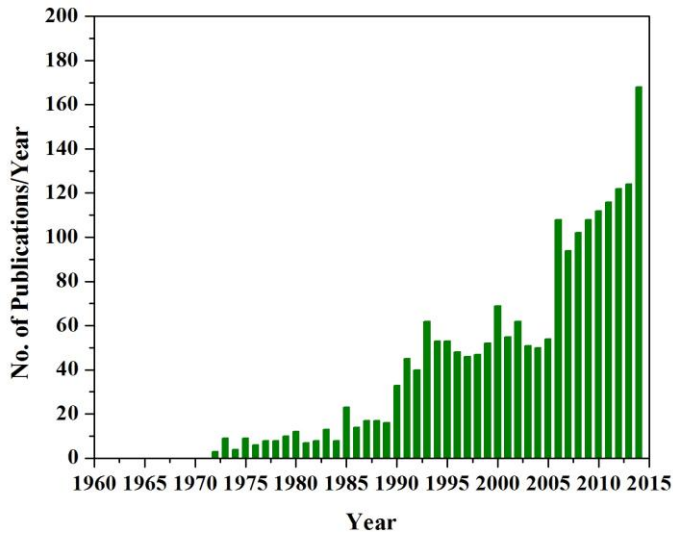


Figure 1: Publication Pattern and Growth of Solar Physics Research in India

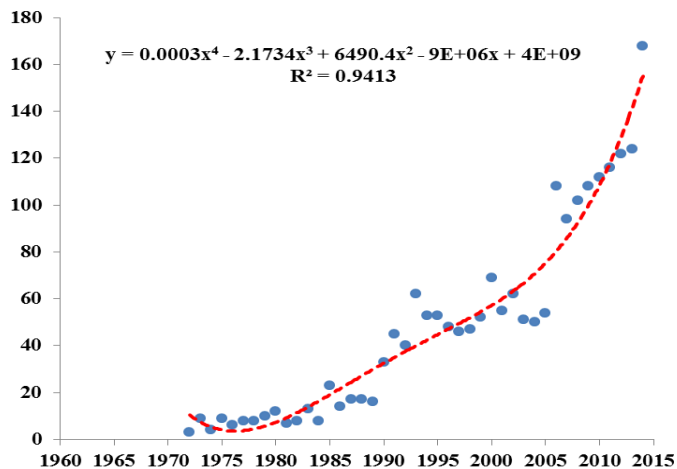


Figure 2: Growth Trend of Solar Physics Research in India

Citation Pattern

Figures 3 and 4 represent the citation pattern and number of citations vs. number of publications per year. A total 22254 citations were received. The pattern of citations is fluctuating. In the initial year 1973, the total number of citations received is 6 with an average citation of 2, which is the minimum citation received during the said period. The maximum citations received in the year 2009 are 1546 with an average citation of 14.31. It has been observed from Figure 4 that after the year 2009, citations decrease while publications continue to increase.

Table 3: Different Regression Types with Regression Coefficient (R^2) of Solar Physics Research

Regression Types	Equation	(R^2)
Exponential	$y = 4E-71e^{0.0831x}$	0.917
Linear	$y = 3.058x - 6048$	0.843
Logarithmic	$y = 6091\ln(x) - 46228$	0.842
Polynomial	$y = 0.0003x^4 - 2.1734x^3 + 6490.4x^2 - 9E+06x + 4E+09$	0.941
Power	$y = 0x165.6$	0.918

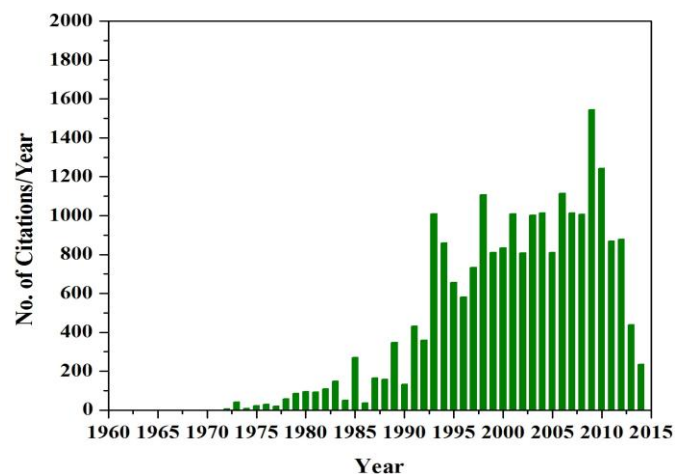


Figure 3: Citation Pattern of Solar Physics Research in India

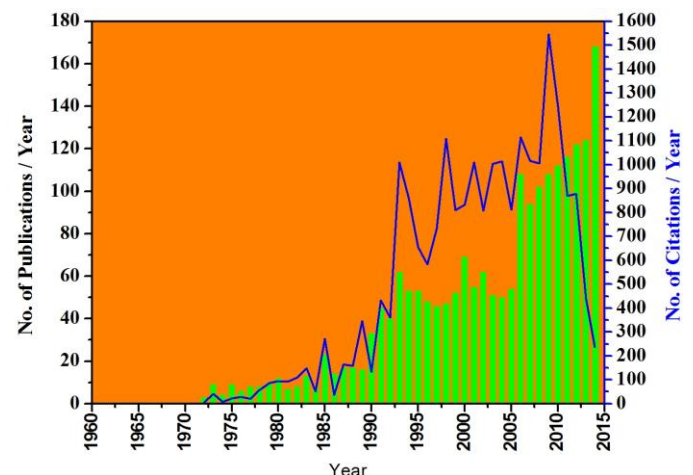


Figure 4: Citation Pattern Vs Publication Pattern of Solar Physics Research in India

Top Institutions and Their Research Impact

Articles on Solar Physics appeared from 1109 institutions. Table 4 shows the top 20 productive institutions during the last 54 years,

1960-2014. Indian Institute of Astrophysics (IIA), Bangalore is the most productive institution with 549 papers, followed by the Physical Research Laboratory (PRL), Ahmadabad with 253 papers and Tata Institute of Fundamental Research, Mumbai with 225 papers. Among the top 20, 8 are foreign institutions namely NASA, USA with 108 papers;

Max Planck Society, Germany with 87 papers; Centre National De La Recherche Scientifique (CNRS), France with 76; Goddard Space Flight Center with 67; Observatoire De Paris, USA with 50; University of California System, USA with 47; Harvard University, USA with 41 and Russian Academy of Sciences, Russia, 40 publications each.

Table 4: Top Institutions on Solar Physics Research and their Research Impact, 1960- 2014

Institution	Region	TP (%)	TC	AvgCPA	h-index
Indian Institute of Astrophysics	India	549(26.573)	5760	10.49	35
Physical Research Laboratory	India	253(12.246)	2291	9.06	21
Tata Institute of Fundamental Research	India	225(10.891)	4537	20.16	38
Aryabhatta Research Institute of Observational Sciences	India	110(5.324)	1115	10.14	16
National Aeronautics Space Administration (NASA)	USA	108(5.227)	2632	24.37	32
Banaras Hindu University	India	88(4.259)	1034	11.75	13
Max Planck Society	Germany	87(4.211)	1848	21.24	24
Indian Institute of Geomagnetism	India	87(4.211)	696	8.00	14
Centre National De La Recherche Scientifique (CNRS)	France	76(3.679)	2318	30.50	28
Indian Institute of Science (IISc)	India	75(3.630)	1805	24.07	25
Inter University Centre for Astronomy Astrophysics	India	73(3.533)	1356	18.58	22
Goddard Space Flight Center	USA	67(3.243)	1603	23.93	22
Indian Institute of Technology IITs	India	62(3.001)	504	8.13	13
Vikram Sarabhai Space Center (VSSC)	India	58(2.807)	598	10.31	13
National Physics Laboratory	India	56(2.711)	279	4.98	10
Observatoire De Paris	USA	50(2.420)	1504	30.08	25
University of California System	USA	47(2.275)	1230	26.17	22
University of Delhi	India	46(2.227)	205	4.46	7
Harvard University	USA	41(1.985)	787	19.20	17
Russian Academy of Sciences	Russia	40(1.936)	716	17.90	16

TP= Total no. of Solar Physics related articles published by an institution; TC = Total no. of citation received; Avg CPA= Average no. of citations per article; h-index=defined by the no. of h papers among an institution's no. of publications that have at least h citations each.

Source: WoS

Table 4 reveals the impact of research in terms of quality of papers. The AvgCPA and the h-index are used to identify which institution has the largest number of high quality articles in the Solar Physics research. It is seen from the Table 4 that Solar Physics related articles authored in foreign organization (Centre National De La Recherche Scientifique CNRS) have the highest average impact (AvgCPA = 30.50) although Indian institution i.e. Indian Institute of Science IISc. Bangalore ranked 5th in the AvgCPA index.

Top Journals and Their Research Impact

Solar Physics papers have appeared in 91 journals. Papers have appeared in highest number in the journal 'Solar Physics' originating from Netherlands published by Springer.

Table 5 shows the top 20 productive journals. These 20 out of the 91 journals have published 1931 (93.46%) of the total 2066 articles. The journal 'Solar Physics' ranked first with 460 (22.26%);

Table 5: Top Journals in Solar Physics Research and their Research Impact, 1960-2014

Journal	TP (%)	TC	Journal Metrics (2013)				Country
			AvgCPA	SJR	IPP	SNIP	
Solar Physics	460(22.265)	4828	10.50	2.256	3.184	1.769	Netherlands
Astrophysical Journal	273(13.214)	5419	19.85	3.159	4.348	1.145	UK
Astronomy Astrophysics	203(9.826)	1811	12.58	1.471	1.932	0.612	France
Journal of Geophysical Research Space Physics	144(6.970)	383	12.85	2.376	3.286	1.412	USA
Astrophysics and Space Science	135(6.534)	383	2.84	1.081	1.748	1.056	Netherlands
Journal of Astrophysics and Astronomy	117(5.663)	326	2.97	0.477	0.541	0.224	India
Advances in Space Research	116(5.615)	353	3.04	0.751	1.416	1.291	Netherlands
Monthly Notices of the Royal Astronomical Society	109(5.276)	2016	18.50	3.196	4.911	1.494	USA
Indian Journal of Radio Space Physics	57(2.759)	71	1.25	0.347	0.514	0.621	India
Annales Geophysicae	57(2.759)	563	9.88	1.176	1.533	1.533	Germany
Planetary and Space Science	37(1.791)	276	7.46	0.925	1.560	0.800	Netherlands
IAU Symposia	35(1.694)	4	0.11	-	-	-	Puerto Rico
Physical Review D	34(1.646)	616	18.12	1.899	3.192	1.136	USA
Astrophysical Journal Letters	31(1.500)	410	13.23	3.914	4.852	1.487	USA
New Astronomy	27(1.307)	209	7.7	1.074	1.332	0.726	Netherlands
Bulletin of the Astronomical Society of India	27(1.307)	55	2.04	1.091	1.068	0.516	India
Annales Geophysicae Atmospheres Hydrospheres and Space Sciences	22(1.065)	159	7.23	-	-	-	Germany
Earth Moon and Planets	18(0.871)	40	2.22	0.303	0.532	0.399	Netherlands
Research in Astronomy and Astrophysics	15(0.726)	81	5.40	0.953	1.331	0.768	UK
Astroparticle Physics	14(0.678)	70	5	3.012	3.828	2.776	Netherlands

TP= Total no. of Solar Physics research related articles published by a Journal; **TC** = Total no. of citation received; **AvgCPA**= Average no. of citations that Solar Physics related articles in a journal received; **h-index**= no. of h papers among a journal's no. of publications that have at least h citations each. **SJR** = SCImago Journal Rank; **IPP** = Impact per Publication; **SNIP** = Source Normalized Impact per Paper.

Source: WoS and SCOPUS

'Astrophysical Journal 273 (13.21%)', 'Astronomy Astrophysics 203 (9.82%)', 'Journal of Geophysical Research Space Physics 144 (6.97%)' and 'Astrophysics and Space Science 135 (6.53%)' ranked at 2nd, 3rd, 4th and 5th respectively.

Table 5 also shows the citation impact of top 20 journals. The AvgCPA and h-index are used to identify which journals have the largest number of high quality articles in the Solar Physics research. It is seen from the Table 5 that the journal 'Astrophysical Journal' published by IOP Publishing for the American Astronomical Society in USA has the highest average impact (AvgCPA = 19.85), it is seen that though the journal 'Solar Physics' has the highest number of publications it is ranked 5th in the AvgCPA index.

Top Authors and Impact of Their Research Output

Articles on Solar Physics have been contributed by 4478 authors. Table 6 showed the top

most productive authors during the last 54 years, 1960-2014. Top most productive authors were ranked based on the decreasing productivity of total publications. Anita, H.M. produced maximum number of publications i.e. 82 and ranked 1st followed by Dwivedi, B. N., Venkatakrishnan, P., Singh, J., Srivastava, A. K. and Basu, S., who ranked 2nd, 3rd, 4th, 5th and 6th respectively.

Table 6 also reveals the impact of research in terms of quality of papers. The AvgCPA and h-index are used to identify which author has the largest number of high quality articles in the Solar Physics research. It is seen from the Table 4.3.l(vi) that Solar Physics related articles authored by Basu, S. have the highest average impact (AvgCPA = 44.73) followed by Choudhuri, A. R. (AvgCPA = 35.53) it is seen that despite of having the maximum number of publications, Antia, H. M. ranked 3rd in the AvgCPA index.

Table 6: Top Authors of Solar Physics Research and their Research Impact

Author	TP (%)	TC	TC woSC	CI	CIwoSC	AvgCPA	h-index
Antia, H.M.	82(3.969)	2551	2276	1415	1343	31.11	30
Dwivedi, B.N.	63(3.049)	880	812	714	677	13.97	13
Venkatakrisnan, P.	62(3.001)	463	388	354	318	7.47	13
Singh, J.	61(2.953)	538	411	337	291	8.82	13
Srivastava, A.K.	51(2.469)	402	274	249	213	7.88	12
Basu, S.	45(2.178)	2013	1877	1179	1141	44.73	28
Ramesh, R.	44(2.130)	332	160	155	118	7.55	10
Manoharan, P.K.	43(2.081)	912	827	663	633	20.73	18
Krishan, V.	41(1.985)	310	253	246	222	7.56	11
Choudhuri, A.R.	40(1.936)	1421	1200	758	723	35.53	22
Hasan, S.S.	39(1.888)	473	422	326	302	12.13	12
Nagendra, K.N.	37(1.791)	261	123	92	59	7.05	10
Lakhina, G.S.	37(1.791)	432	408	368	355	11.68	12
Jain, R.	37(1.791)	207	162	166	142	5.59	8
Banerjee, D.	37(1.791)	525	468	374	353	14.19	13
Chitre, S.M.	34(1.646)	540	497	422	398	15.88	13
Shanmugaraju, A.	33(1.597)	239	176	153	129	7.24	9
Uddin, W.	32(1.549)	347	297	261	238	10.84	11
Sivaraman, K.R.	31(1.500)	582	533	416	393	17.12	15
Srivastava, N.	30(1.452)	353	316	272	258	11.77	10

TP: Total no. of Solar Physics related articles published by an author; **TC:** Total no. of citation; **TC woSc:** Sum of Times Cited without self-citations; **CI:** Citing Articles; **CIwoSC:** Citing Articles without self-citations; **AvgCPA:** Average Citations per Article; **h-index:** no. of h papers among a author's no. of publications that have at least h citations each.

Source: WoS

Collaboration Pattern: Continents

World-wide collaboration in Solar Physics research publications has been mapped. As shown in Figure 5, the major spatial clusters of research institutes are located in Europe followed by Asia, Africa and South and North America. Minor clusters are distributed in Australia

Country Wise Collaboration & Research Impact

A total of 2066 articles included author address, source country and research institute. There are 65 Countries/territories which participated in Solar Physics research. As shown in the Table 7, top 20 countries / territories are ranked based on the number of total articles, along with the citations and percentage of internationally collaboration publications. Out of these 20 countries / territories, The USA produced maximum publications - 420 which is 20.32% of total publications with citations (8711). It is seen from the Table 7 that Solar Physics

related articles authored in Denmark have the highest average impact (AvgCPA = 45.16) while USA ranked 10th in the AvCPA index.

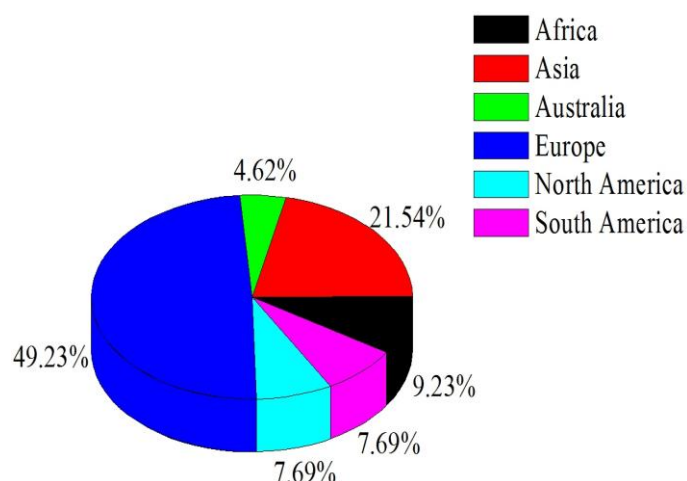


Figure 5: Continent Wise Collaboration Pattern of Solar Physics Research

Collaboration Pattern and Research Impact: Countries

Table 7: Country Wise Collaboration Pattern and research impact of Solar Physics research

Country	Continent	TP(%)	TC	AvCPA	h-index
USA	North America	420(20.329)	8711	20.74	49
Germany	Europe	137(6.631)	2708	19.77	30
Japan	Asia	103(4.985)	1186	11.51	18
England	Europe	102(4.937)	2611	25.60	32
France	Europe	100(4.840)	2959	29.59	32
South Korea	Asia	57(2.759)	560	9.82	16
Russia	Europe	47(2.275)	669	14.23	16
Spain	Europe	44(2.130)	1116	25.36	19
Switzerland	Europe	43(2.081)	546	12.70	14
North Ireland	Europe	43(2.081)	546	12.70	13
Italy	Europe	42(2.033)	1096	26.10	19
Brazil	South America	42(2.033)	624	14.86	12
Belgium	Europe	31(1.500)	523	16.87	11
Peoples R China	Asia	30(1.452)	469	15.63	11
Australia	Australia	30(1.452)	863	28.77	15
Denmark	Europe	25(1.210)	1129	45.16	17
Austria	Europe	24(1.162)	552	23.00	13
Sweden	Europe	22(1.065)	495	22.50	9
Netherlands	Europe	22(1.065)	800	36.36	14
Canada	North America	22(1.065)	499	22.68	12

TP= Total no. of Solar Physics related articles published by a country; *TC* = Total no. of citation received; *AvgCPA*= Average no. of citations per Article; *h-index*= no. of *h* papers among a country's no. of publications that have at least *h* citations each.

Source: WoS

Keyword Analysis

The process of keyword analysis has been described by various authors in many ways. Li and Zhao performed the keyword analysis to demonstrate research trends and frontiers. The keywords analysis in their study utilised author keywords, which were provided by article authors as part of the articles and termed as Keywords [4]. Another such analysis was used in a study by Montoya et al., 2014 in order to follow and search the trends in the science and engineering [5]. Yanhua et al. [6] used keyword analysis to reveal the trends and identify hot topics that draw most research efforts. In another study, the authors mention that keywords provide a reasonable description of an article's theme and could reveal the profile of an author's research preferences [7].

A total of 5657 different keywords, from 1960 to 2014 in the Solar Physics have been identified. Of the total papers only 1775 provided key words. To obtain accurate results, the keywords were normalized by merging the

singular and plural forms, and those keywords with the same meaning while using different expressions (for example, "coronal mass ejections", "Coronal mass ejection", "Coronal mass ejections (CMEs)", "cme" and "CMEs", "magnetic-field", "magnetic fields" and "Magnetic field", "solar-flare", "Solar flare" and "Solar flares"). A total 4808 unique keywords were identified. Among these unique keywords 3313 (68.91%) appear once or twice at the most. Table 8 shows the most used keywords, whereas Figure 6 indicates the evolution different top 10 Author Used Keyword in Solar Physics Research.

Hotspots

An analysis of the keywords was undertaken to pick out the research hotspots that have attracted most research attention and to reveal the research tendencies in the fields of Solar Physics. The top most frequently used keywords for the study period are listed in Table 8. The four most frequently used

keywords were 'Corona', 'Flares', 'Magnetic Fields' and 'Coronal Mass Ejections'.

Table 8: Top Most Frequently Used Keywords in Solar Physics Research

Keyword	No.	%	R
Corona	415	8.63	1
Flares	266	5.53	2
Magnetic Field	260	5.40	3
Coronal Mass Ejections	245	5.09	4
Activity	245	5.09	5
Oscillation	237	4.92	6
Atmosphere	194	4.03	7
Sunspots	182	3.78	8
Evolution	149	3.09	9
Rotation	146	3.03	10
Solar Wind	92	1.91	11
Active Region	85	1.76	12
Chromosphere	79	1.64	13
Interior	79	1.64	14
Filaments	73	1.51	15
Photosphere	67	1.39	16
Prominences	58	1.20	17
Abundances	52	1.08	18
Transition Region	51	1.06	19
Radio Region	49	1.01	20

NO: Number of time occurrences; R: rank.

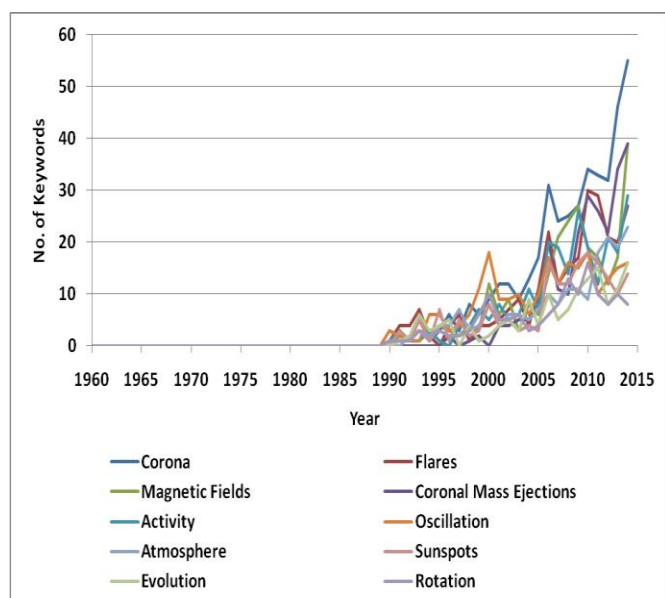


Figure 6: Evolution of top author used keyword in Solar Physics Research during 1960-2014

Quick Rising Theme

The Compound Annual Growth Rate (CAGR) was used to identify the top most frequently used keywords to identify themes of Solar Physics that are indicative of future research directions. The CAGR of top keywords was separately calculated based on the following formula:

$$CAGR(t_0, t_n) = (V(t_n)/V(t_0))^{\frac{1}{t_n - t_0}} - 1$$

$V(t_0)$: Initial observed value, $V(t_n)$: last observed value, $t_n - t_0$: number of years [Compound annual growth rate, n.d.].

The CAGR provides smoothed growth rates free from the annual fluctuations of keywords occurrences during the study period. Table 9 lists the top keywords according to the CAGR and sorted them by their rank. The ranks in Table 9 show that 'Coronal Mass Ejections' and 'Activity' and 'Flares' are three leading hot issues that continue to attract broad attention. 'Coronal Mass Ejections' kept its dominance in terms of total quantity and CAGR (0.179%).

CONCLUSION

A total number of 2066 publications were brought out in Solar Physics, which in all received a total of 22254 citations. The average number of publications per year was 48.04 and the average number of citations per publication was 10.77. Articles on Solar Physics appeared in 92 journals, of which 'Solar Physics' was found to be most productive journal, published by Elsevier Science from Netherlands. It carried a total number of 460 (22.26%) of the total. Of the 1109 institutions that have contributed, Indian Institute of Astrophysics, Bangalore (549) is the most productive institution. For globalization of Solar Physics Research in India, there were 65 Countries/territories which participated in collaborative research. The USA produced maximum number of publications i.e. 420 of the total publications with 8711 citations. A Keyword analysis reveals that Corona, Flares, Magnetic Fields, Coronal Mass Ejections, Activity, Oscillation, Atmosphere are the most used keywords.

Table 9: Top Quick rising themes in Solar Physics research

Keyword	V (t_0)	V (t_n)	t_0	t_n	CAGR (%)	R
Abundances	3	3	1992	2014	0.000	20
Active region	1	7	1991	2014	0.088	12
Activity	1	29	1990	2014	0.150	2
Atmosphere	2	23	1992	2014	0.117	8
Chromosphere	2	7	1990	2014	0.053	18
Corona	3	55	1991	2014	0.134	5
Coronal Mass Ejections	2	39	1996	2014	0.179	1
Evolution	1	16	1991	2014	0.128	7
Filaments	2	10	1991	2014	0.072	13
Flares	1	27	1990	2014	0.147	3
Interior	1	6	1993	2014	0.089	11
Magnetic Fields	2	39	1991	2014	0.137	4
Oscillation	3	16	1990	2014	0.072	14
Photosphere	2	9	1990	2014	0.064	16
Prominences	1	10	1995	2014	0.128	6
Radio radiation	1	4	1991	2014	0.062	17
Rotation	1	8	1990	2014	0.090	10
Solar Wind	1	9	1994	2014	0.116	9
Sunspots	3	14	1991	2014	0.069	15
Transition region	1	3	1991	2014	0.048	19

t_0 : the Initial (first) year (The Year in which no. of keywords occurrence first time; t_n : the last year (No. of keywords occurrence); V (t_0): Initial observed value (no. of keywords occurrence); V (t_n): last observed value (no. of keywords occurrence); **CAGR**: Compound Annual Growth Rate; **R**: Rank.

Source: WoS

REFERENCES

- [1] *Astronomical Subject Keywords*. (2013). <https://aas.org/authors/astronomical-subjectkeywords-update-august-2013> [accessed 23 July 2014].
- [2] Ayres, T. & Longcope, D. (2012). *Ground-Based Solar Physics in the Era of Space Astronomy*. <http://www.hao.ucar.edu/CommunityWorkshopGroundBasedSolarResearch/whitePages/GroundBased%20Solar%20Physics%20in%20the%20Era%20of%20Space%20Astronomy.pdf>. [accessed 14 March 2016].
- [3] *Compound annual growth rate*. (n.d.). In Wikipedia: https://en.wikipedia.org/wiki/Compound_annual_growth_rate [accessed 24 April 2015]
- [4] Li, W. & Zhao, Y. (2015). Bibliometric Analysis of Global Environmental Assessment Research in a 20-year period. *Environmental Impact Assessment Review*. 50, 158–166.
- [5] Montoya, F.G. et al. The research on Energy in Spain: A Scientometric Approach. *Renewable and Sustainable Energy Reviews*. 29, 2014, 173-183. doi:10.1016/j.rser.2013.08.094 [accessed 22 November 2015].
- [6] Yanhua, Z et al. Research Trends in Non-Point Source during 1975-2010. *Physics Procedia*. 33, 2012, 138-143. doi:10.1016/j.phpro.2012.05.041 [accessed 22 November 2016].
- [7] Niu, B., Loáiciga, H. A., Wang, Z., Zhan, F. B. & Hong, S. Twenty years of global groundwater research: A Science Citation Index Expanded- based bibliometric survey (1993–2012). *Journal of Hydrology (Part A)*. 519, 2014, 966–975. <http://doi.org/10.1016/j.jhydrol.2014.07.064> [accessed 31 August 2016].